PAPER MICROFLUIDIC DEVICES FOR DETECTION OF IMPROVISED EXPLOSIVES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. application Ser. No. 14/216,869, filed Mar. 17, 2014, which claims the benefit of U.S. Provisional Application Ser. No. 61/794,955, filed Mar. 15, 2013, both of which are hereby incorporated by reference in their entireties, including any figures, tables, and drawings.

GOVERNMENT SUPPORT

The subject invention was made with government support under a research project supported by National Institute of Justice Award No. NIJ 20012-90426-FL-DN. The government has certain rights in this invention.

BACKGROUND

Improvised or homemade explosives (HMEs) were once limited to war zones but have recently become a concern for law enforcement and other first responders in the United States and abroad. Such responders may encounter organized groups or curious "citizen scientists" synthesizing HMEs. Fast and accurate identification of the explosive compound used is of the utmost importance. Common constituents of HMEs include organic and inorganic compounds, sugars, and elemental metals. Many different analytical technologies exist for detecting and quantifying explosive materials; however, the different unregulated and easily obtained compounds used in the devices vary greatly in molecular mass, structure, and physicochemical properties, and no single analytical instrument has the capability to identify them all.

A number of different techniques are available for the identification of explosive compounds. Gas chromatography/mass spectrometry (GC/MS), liquid chromatography/mass spectrometry (LC/MS), or Fourier transform infrared spectroscopy (FT-IR) may be used for organic and inorganic compounds while ion chromatography (IC) and capillary electrophoresis (CE) may be used for inorganic ions. Metals can be detected by scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDS) or by X-ray diffraction (XRD). Some compounds require electrospray ionization mass spectroscopy (ESI-MS) to be identified in a sample. These detection techniques have similar shortcomings; they require large, expensive pieces of instrumentation that, with the exception of FT-IR, are not portable. Due to vacuum, power, and gas requirements, the instruments required for these techniques are necessarily centrally located. Thus, the sample must be collected and brought to the laboratory, thereby increasing the amount of time before any analytical information on the identity of the explosive can be obtained and, e.g., provided to first responders.

Additionally, samples may need to undergo preparative techniques, such as filtration or extraction before instrumental analysis can be performed, thereby increasing the total analysis time. This also increases the potential for analytes to be lost through such processes by adsorption onto the filtration medium or degradation of the sample by interaction with the extraction solvent. Samples must also be prepared in sufficient volume (generally at least 200 μL per instrument) to be handled by an auto-sampler.

BRIEF SUMMARY

The subject invention provides devices and methods for detection of explosives, e.g., improvised explosives or homemade explosives (HMEs). In one embodiment, a paper microfluidic device (PMD) can be used to detect explosives, such as improvised explosives and/or HMEs.

In an embodiment, a PMD of the subject invention includes one or more hydrophobic channels on a paper substrate and a test reagent provided at a test spot of at least one of the hydrophobic channels. The test reagent is configured or adapted to test for one or more improvised explosives or HMEs. The test spot can be a colorimetric test spot.

In another embodiment, the subject invention provides a method of testing a sample for explosives (e.g., improvised explosives and/or HMEs), wherein the method includes providing the sample to a PMD. The PMD includes one or more hydrophobic channels on a paper substrate and a test reagent provided at a test spot of at least one of the hydrophobic channels. The test reagent is configured or adapted to test for improvised explosives or HMEs. The sample can be provided to the PMD in a very small amount (e.g., 50 μL or less). For example, the sample can be provided to the PMD in a volume of 35 μL or about 35 μL.

In yet another embodiment, the subject invention provides a method of fabricating a PMD, wherein the method includes printing a wax pattern onto a paper substrate (e.g., filter paper or chromatography paper) and heating the paper substrate, thereby allowing the liquid wax to penetrate the paper substrate. One or more test reagents can be provided to test spots in the channels formed by the wax. The test reagent is configured or adapted to test for improvised explosives or HMEs.

In yet another embodiment, the subject invention provides a kit that includes a PMD. The PMD includes one or more hydrophobic channels on a paper substrate. The PMD may have test reagents already present for spot tests or may have no test reagents present on the PMD. The kit may additionally include one or more test reagents. The test reagents are configured or adapted to test for improvised explosives or HMEs. A user can apply the test reagents to the testing sites of a PMD that does not already have the test reagents present.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**D show a process of fabricating a paper microfluidic device (PMD) according to an embodiment of the subject invention.

FIGS. **2**A-**2**C show examples of the movement of samples through a three-dimensional PMD according to an embodiment of the subject invention.

FIG. **3** shows a PMD according to an embodiment of the subject invention.

FIG. **4** shows a PMD according to an embodiment of the subject invention.

FIG. **5** shows the results of a test of p-DMAC as a test reagent for urea nitrate.

FIG. **6** shows the results of a test of ammonium titanyl oxalate as a test reagent for peroxide.

FIG. **7** shows the results of a test for ammonium ion using different solvents.

FIG. **8**A shows an image of a PMD according to an embodiment of the subject invention.

FIG. **8**B shows an image of a PMD according to an embodiment of the subject invention.